Measurement of Depositing and Bombarding Species Involved in the Plasma Production of Amorphous Silicon and Silicon/Germanium Solar Cells

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The technical approach to this project, and the apparatus design to achieve it, was described in two previous quarterly reports. Briefly, we will utilize mass spectrometry to measure radical and ion species that arrive at the substrate of a plasma-enhanced-chemical-vapor-deposition (PECVD) reactor. The reactor will mimic those used to produce hydrogenated amorphous (a-Si:H) and microcrystalline (μc-Si) silicon and silicon/germanium (a-Si:Ge:H) solar cells. Radio frequency (RF) and high frequency (HF) discharges will normally be studied. The reactor will utilize similar electrode gap (2-3 cm), substrate temperature (20-250 °C), gas pressures (0.1-5 Torr), gas mixtures and discharge power density to that used in an industrial reactor.

All of the apparatus has now been constructed, and assembly is underway. Three turbomolecular pumps and accompanying rough pumps will evacuate several parts of a vacuum chamber. A quadrupole mass spectromerter (QMS) will be used for detecting radicals at the discharge substrate surface. This QMS has been significantly modified, as is necessary for use in threshold ionization mass spectrometry (TIMS). The discharge and TIMS regions are inserted into a ~ 3" diameter cylindrical opening in a 6″x 6″x 9″ stainless-steel block, and are connected by two small orifices and three stages of differential pumping. Conflat flange fittings are machined directly into the surfaces of the stainless steel block for mounting the discharge and QMS structues. Viton O-rings at the tube surface ensure vacuum integrity between the several chambers. This arrangement was shown diagrammatically and explained in the previous quarterly report, and this diagram is repeated here (Fig.1) to assist in understanding the now-constructed apparatus.

Since the last report, the electron beam optics and the ion-collection lenses have been fully designed and constructed. Fig.2 is a photograph of the assembled electron and ion optics. These elements are mounted on a poly-crystal-alumina plate, for reliable insulation and structural integrity at elevated temperatures produced by the ~ 1000 °C cathode. The electron beam is confined by a magnetically field of ~ 50 Gauss, produced by the two small (rare earth) magnets at the far edges of Fig.1. This magnetic field is sufficient to confine the electrons to a ~ 1 mm diameter beam, but small enough to avoid influencing the ion orbits. The electron beam current is controlled by a “anode” immediately in front of the cathode, so that it can be held constant while the electron energy is scanned in TIMS. A “Faraday cup” collects this current for control and analysis. Also, fringing fields at the discharge are below 5 Gauss, and will not influence the discharge at normal gas pressures. The role of the ion optics is to direct a large fraction of ionized radicals into the QMS. Calculations using the SIMION program indicate that this can be achieved, but this remains to be tested.

The gas handling system, not shown, includes a ~ 950 °C gas pyrolizer between the turbomolecular and rough pumps, to break down the silane and germane gases into Si and Ge coatings plus hydrogen gas that can be vented safely. Similarly, ultra-high vacuum, stainless steel valves control the inlet and outlet gas flows. Fig.3 is a photograph showing this ionizer mounted onto the QMS, with a vapor-blocking, insulating plate between to allow differential pumping of the QMS.

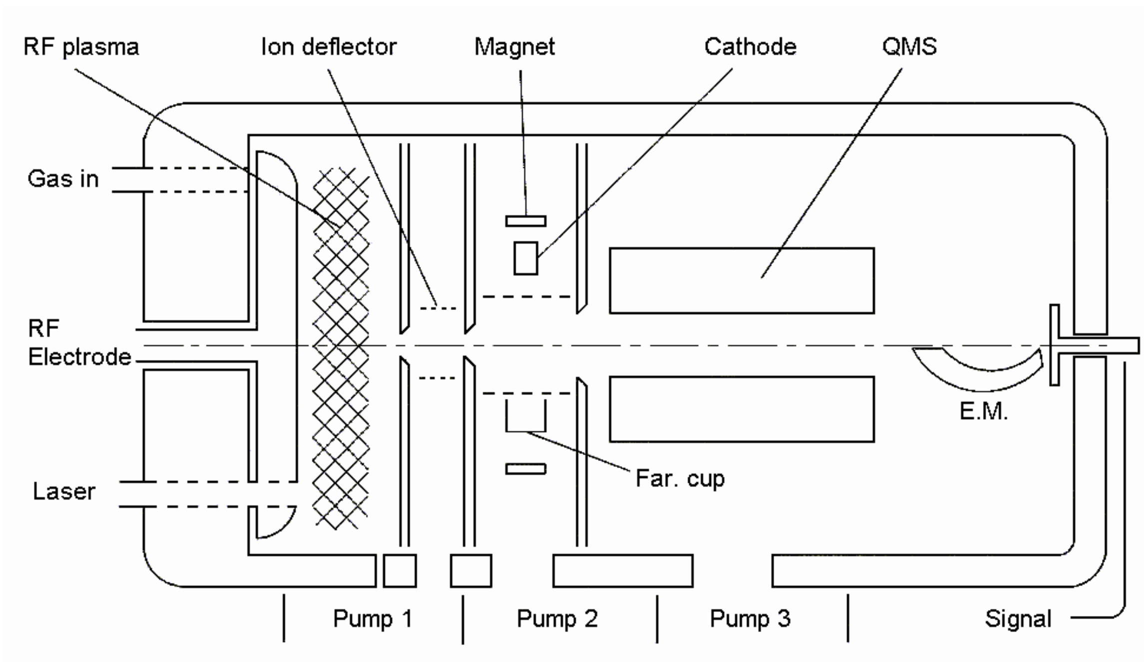

Fig.1. Diagrammatic representation of the apparatus designed for discharge radical detection by threshold ionization mass spectrometry. Discharge radicals pass through two, 1 mm diameter apertures into the ionizer region, then ions are focused through a 5 mm aperture into the mass spectrometer. When biased, the ion-deflector screens prevent discharge ions from entering the mass spectrometer, for detecting neutral radicals. Discharge ions can be studied by removing the bias.

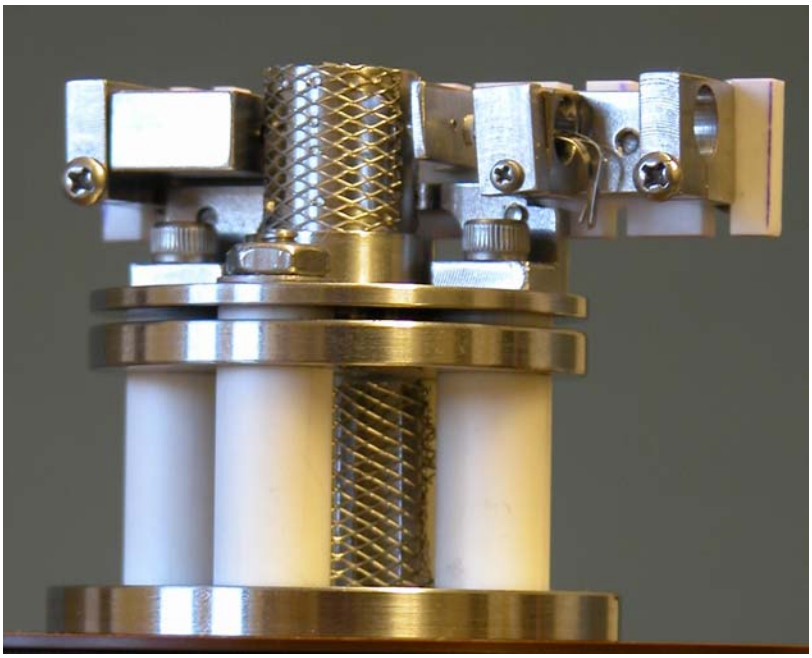

Fig.2. Photograph of the electron beam and ion optics portion of the apparatus, including the supporting structures. The electron beam traverses horizontally across the top of the figure, while the ions are collected by the 1 cm diameter screen lenses, with vertical axes, and directed into the MS below. The magnets that confine the electron beam are at the top, far right and left. The cathode is the next element from the right, followed by the anode that accelerates the electrons to ~ 3 eV and controls the current. The Faraday cup is immediately to the left of the screens. The aperture to the discharge chamber is immediately above the top ion lens.

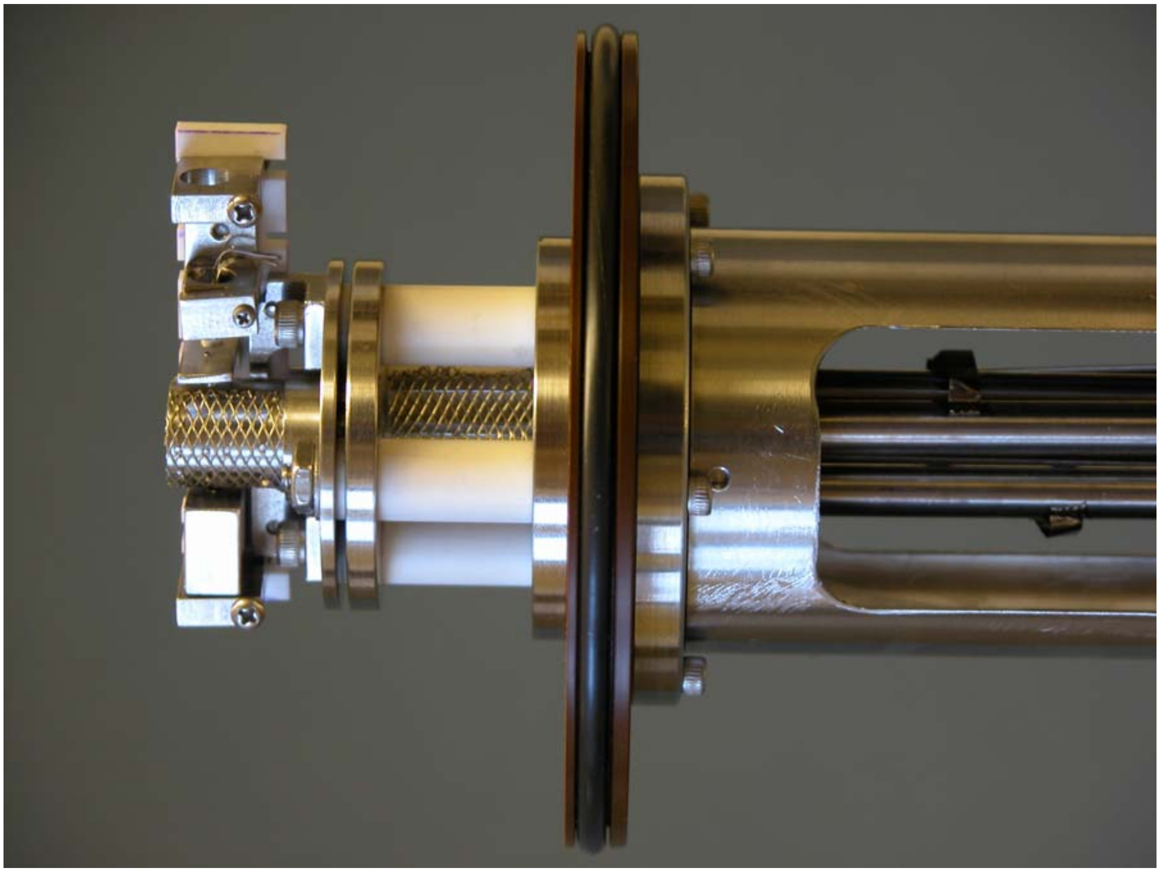

Fig.3. Photograph of the ionizer and ion optics mounted on the QMS. The rods of the QMS are visible at the right, inside the ~ 2” diameter supporting cylinder.